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An analysis of age and body weight at first calving for Holsteins in the United States

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Abstract

In a national survey of US dairy producers, only $2.7 \pm 0.5\%$ of Holstein dairy operations reported achieving recommended target ranges of age ≤ 24 months and body weight (BW) ≥ 550 kg at first calving. Allowing for wider target ranges, still only $14.6 \pm 1.3\%$ of Holstein dairy operations reported achieving age ≤ 25 months and BW ≥ 544.3 kg at first calving. Ages of individual first-calf heifers observed at calving were heavily skewed toward older individuals. Dairy producers reported an average age at first calving that was 1.3 months lower than the mean and 1.0 months lower than median age of first-calf heifers' observed calving on the operations. Stepwise logistic regression was used to identify the herd characteristics associated with producers reporting first calvings within the wider age and BW target ranges for Holsteins. Rolling herd average milk production ≥ 7711 kg/yr, using a computer for recordkeeping, and not tying preweaned heifers in a barn with cows, were associated with achieving the target BW and age at first calving. © 1997 Elsevier Science B.V.

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1. Introduction

An important factor in the cost of raising dairy replacements is age at first calving (Goodger et al., 1989; Lin et al., 1988). Reduced age at first calving offers advantages

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such as lower overhead costs, decreased feed costs, decreased overcrowding, and increased production per day of herd life (Goodger et al., 1989; Lin et al., 1988).

Body weight (BW) at calving is positively related to first-lactation milk production (Miller and McGilliard, 1959). In addition, BW at first calving is a significant factor in the successful delivery of a calf (Hoffman and Funk, 1992). A certain minimum BW at first calving must be maintained to minimize dystocia and maintain high milk production (Heinrichs, 1993). For Dairy Herd Improvement Association herds in Pennsylvania, Heinrichs and Vazquez-Anon (1993) noted a decrease in age at first calving from 1985 to 1990 for Holsteins, with no change in BW. Current recommendations for producers are for Holstein heifers to calve at 24 months of age or less, and to weigh 550–600 kg (Daccarett et al., 1993; Heinrichs, 1993). Dairy producers and those associated with the dairy industry require a better understanding of factors that affect a manager's ability to optimize age and BW at first calving.

The principal objectives of this study were to use data collected from the US National Animal Health Monitoring System (NAHMS) 1991–1992 National Dairy Heifer Evaluation Project (NDHEP) to determine the percentage of US Holstein dairy producers that attained the recommended age and BW at first calving, and to identify the characteristics associated with achieving the target age and BW at first calving. A secondary objective was to determine how accurately NDHEP respondents provided information on age at first calving.

2. Materials and methods

The NDHEP was a yearlong NAHMS study conducted by the United States Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services (Erb et al., 1996; Heinrichs et al., 1994; US Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services, 1993a,b). Details on the objectives and design of the NDHEP have been published (Heinrichs et al., 1994).

Enumerators from the USDA:National Agricultural Statistics Service (NASS) visited dairy operations and administered a questionnaire on general dairy management, including average age and BW at first calving (Heinrichs et al., 1994). BW was recorded in pounds and converted to kilograms by multiplying by 0.4536. In addition, over a 90-day period, a subset of NDHEP participants recorded dam age and parity on a calving log (US Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services, 1994). Statistical analyses were restricted to dairy operations that reported their principal breed to be Holstein, because Holsteins tend to be larger, calve later than other dairy breeds, and accounted for $94.9 \pm 0.7\%$ of the dairy operations in the US in 1991–92 (Heinrichs et al., 1994).

2.1. Comparison of reported and observed ages at first calving

The SAS MEANS procedure (Statistical Analyses Systems Institute, 1990) was used to compute a mean age for first-calving dams for each Holstein operation that had completed a calving log with information from at least one first-calving dam. The median age for first-calving dams for the same operations was computed with the SAS UNIVARIATE procedure (Statistical Analyses Systems Institute, 1990). 'Reported' average age at first calving refers to the average age at first calving that the producer reported on the NASS questionnaire, and 'observed' age at first calving refers to ages actually observed on the calving log. A paired t-test (Snedecor and Cochran, 1967) was used to compare the reported average age at first calving, which the producer reported on the questionnaire, with the mean and median observed ages at first calving (observed from the calving log). In addition, a sign test (Snedecor and Cochran, 1967) was used to test the null hypothesis that the mean and median observed ages at first calving had the same distribution as the reported average age at first calving.

2.2. Operations approaching target calving age and weight

Unweighted estimators using data collected in a sample survey with stratified sampling can be severely biased (Korn and Graubard, 1995). Therefore, SUDAAN (a computer program specifically designed for multistage survey data analysis; Research Triangle Institute, 1992) was used to obtain national estimates and standard errors of mean BW at first calving, mean age at first calving, percentage of operations reporting first-calving BW ≥ 550 kg and age ≤ 24 months, and percentage of operations reporting first-calving BW ≥ 544.3 kg (i.e., 1200 lb) and age ≤ 25 months for Holstein dairy operations. SUDAAN accomplishes this through the Taylor Series approximations (Research Triangle Institute, 1992).

Because very few operations reported achieving the recommended ≥ 550 kg and ≤ 24 months at first calving, the CROSSTAB procedure of SUDAAN (Research Triangle Institute, 1992) was used to compute the percentage of Holstein operations that reported first-calving BW ≥ 544.3 kg (i.e., 1200 lb) and age ≤ 25 months for 32 different herd characteristics. Herd-level management practices were defined as management practices, which the producer reported on the questionnaire administered by the NASS enumerator, that were routinely applied as a matter of general herd policy on the operation.

2.3. Multivariable models

A χ^2 test (CROSSTAB procedure; Research Triangle Institute, 1992) was performed on each of the 32 dairy-operation characteristics to test the null hypothesis of no relationship between the characteristic and reporting BW ≥ 544.3 kg and age ≤ 25 months at first calving. This test served as an initial screening to determine whether individual herd-level characteristics should be considered for inclusion in a multivariable logistic regression model. Herd-level management practices with $P < 0.10$ were considered to have passed this initial screening. To explore the possibility of collinearity among the model's explanatory variables (Hosmer and Lemeshow, 1989), the CORR procedure of SAS (Statistical Analyses Systems Institute, 1990) was used to examine Spearman rank correlation coefficients (Hogg and Craig, 1978) among the screened variables.

To compare solutions and validate findings, both the PROBIT procedure of SAS (Statistical Analyses Systems Institute, 1989) and SUDAAN's logistic regression proce-

Table 1
Percentage of operations that were primarily Holstein (1811 National Dairy Heifer Evaluation Project herds, 1991–92, USA)

	Percent	Standard error
Overall	94.9	0.7
Region		
West	90.6	2.1
Midwest	95.5	1.0
Northeast	94.8	1.4
Southeast	94.1	1.5
Milking plus dry dairy cows, no.		
< 100 cows	94.3	0.9
100–200 cows	97.5	0.7
> 200 cows	96.1	1.1

dure (Research Triangle Institute, 1992) were used to build multivariable logistic regression models. The process included only dairy operations that had provided data for all of the screened-through variables. The log odds of a dairy operation reporting that first calvings occurred within the target ranges for mean BW and mean age served as the dependent variable. As in previous NDHEP analyses (Garber et al., 1994; Losinger and Heinrichs, 1996; Losinger et al., 1995), 4-region and 3-herd size categories were forced into the model to make certain that other variables did not enter the model merely because of regional or herd size differences.

For the development of the logistic regression model using the SAS PROBIT procedure, simple random sampling was assumed. Sample weights and information on the sample design were not used. The log likelihood (furnished by the procedure) was used to select variables (Hosmer and Lemeshow, 1989). A forward stepwise variable selection method was employed to develop the final logistic regression model (Hosmer and Lemeshow, 1989). The P-value for variables entering or leaving the model was 0.05.

Table 2
Percentage of primarily Holstein operations by average age at first calving and average BW at first calving as reported by the producer (1702 primarily Holstein herds in the National Dairy Heifer Evaluation Project, 1991–92, USA)

	Percent	Standard error
Average age at first calving		
≤ 24 months	37.2	1.9
> 24, ≤ 25 months	11.7	1.2
> 25, ≤ 27 months	28.3	1.7
> 27 months	22.8	1.6
Average BW at first calving		
< 453.6 kg	7.6	1.1
≥ 453.6, < 499.0 kg	18.8	1.5
≥ 499.0, < 544.3 kg	38.3	1.8
≥ 544.3, < 550.0 kg	22.8	1.5
≥ 550 kg	12.5	1.2

Table 3
Percentage of primarily Holstein operations that reported average age ≤ 25 months and average BW ≥ 544.3 kg at first calving by various management practices (1702 primarily Holstein herds in the National Dairy Heifer Evaluation Project, 1991–92, USA)

	Percent	Standard error
Variables with $P \leq 0.10$ on χ^2 (and offered to multivariable modelling)		
Region		
West	26.1	3.3
Midwest	16.6	2.0
Northeast	9.5	1.8
Southeast	5.8	1.9
Milking and dry dairy cows, no.		
< 100 cows	13.4	1.5
100–200 cows	16.7	3.5
> 200 cows	28.9	3.6
Rolling herd average milk production		
< 7711 kg	9.1	1.7
≥ 7711 kg	19.9	2.0
Calves are hand-fed < 3.79 l of colostrum during first 24 h		
Yes	12.5	1.6
No	16.8	2.1
Mean age of calves when first offered grain or other concentrated feed		
≤ 6 days	18.4	2.8
> 6 days	12.7	1.4
Mean age of calves when first offered hay or other roughages		
≤ 20 days	11.3	1.5
> 20 days	19.1	2.3
Unweaned heifers are tied in cow barns		
Yes	5.0	1.8
No	16.4	1.5
Unweaned heifers are housed in individual pens in other barns		
Yes	22.6	3.9
No	12.5	1.2
Unweaned heifers are tied in other barns		
Yes	5.0	1.8
No	16.4	1.5
A computer is used for recordkeeping		
Yes	23.7	3.5
No	11.9	1.3
Variables with $P > 0.10$ (not further modelled)		
Operation is a Grade A dairy operation		
Yes	14.8	1.4
No	12.7	3.9
% of dairy herd that is registered		
0	15.7	1.9
> 0, ≤ 25%	12.5	2.4
> 25%	13.5	2.4
How soon newborn calves are separated from dams		
< 12 h	14.8	1.6
≥ 12 h	14.3	2.4

Table 3 (continued)

	Percent	Standard error
Calves receive first colostrum through nursing dam		
Yes	15.3	2.7
No	14.3	1.4
Mean age of calves when first offered free choice of water		
< 20 days	14.7	85.3
≥ 20 days	14.9	85.1
Mean age of calves at weaning		
≤ 6 weeks	17.5	2.8
> 6, ≤ 9 weeks	13.9	1.7
> 9 weeks	11.3	2.0
Unweaned heifers run loose in a lot or pasture		
Yes	10.3	4.5
No	14.9	1.4
Unweaned heifers are housed in individual hutches		
Yes	17.1	2.0
No	13.3	1.7
Unweaned heifers are housed in group hutches		
Yes	14.8	6.0
No	14.6	1.4
Unweaned heifers are housed in individual pens in cow barns		
Yes	11.8	2.5
No	15.1	1.5
Unweaned heifers are housed in group pens in cow barns		
Yes	12.0	2.5
No	15.4	1.5
Unweaned heifers are housed in group pens in other barns		
Yes	11.1	2.7
No	15.3	1.5
Unweaned heifers are on wood floors		
Yes	24.6	6.2
No	14.3	1.4
Unweaned heifers are on concrete floors		
Yes	13.8	1.8
No	16.1	1.8
Unweaned heifers are on stone or gravel floors		
Yes	14.0	4.4
No	14.7	1.4
Unweaned heifers are on metal floors		
Yes	14.2	9.5
No	14.6	1.3
Unweaned heifers are on dirt floors or pasture		
Yes	14.6	1.7
No	14.6	1.8
Person with major responsibility for care and feeding of unweaned heifers		
Operator or spouse	14.5	1.6
Someone else	15.0	2.2
Sex of person with major responsibility for care and feeding of unweaned heifers		
Male	14.0	1.5
Female	16.2	2.5

Table 3 (continued)

	Percent	Standard error
DHIA recordkeeping system is used		
Yes	15.2	1.7
No	13.8	2.0
Milk from cows recently calved is fed after colostrum		
Yes	14.7	1.8
No	14.5	1.8
Whole milk from bulk tank is fed after colostrum		
Yes	15.6	2.1
No	14.1	1.7
Mastitic or antibiotic milk is fed after colostrum		
Yes	15.7	2.2
No	14.0	1.6
Milk replacer is fed after colostrum		
Yes	16.1	1.9
No	12.5	1.6
Fermented milk is fed after colostrum		
Yes	20.7	7.6
No	14.4	1.3

The participating states included in each region were as follows: West: California, Colorado, Idaho, Oregon and Washington; Midwest: Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, Ohio and Wisconsin; Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New York, Pennsylvania, Rhode Island and Vermont; Southeast: Alabama, Florida, Georgia, Maryland, North Carolina, Tennessee and Virginia.

The model developed from SUDAAN made use of the sample weights and sample design (Research Triangle Institute, 1992). Because overall model deviance estimates given by SUDAAN did not reflect the design weights or design stratification or clustering, the individual *P*-values from Wald's tests were used to determine which variables entered or left the model. A *P*-value < 0.05 was required to enter and remain in the model.

3. Results

Of 1811 NDHEP participants, 1702 (94.0%) were mainly Holstein dairy operations (Table 1). The weighted national estimate (using SUDAAN) was $94.9 \pm 0.7\%$ of US dairy operations having Holstein as the principal breed.

Of the 1702 Holstein dairy operations participating in the NDHEP, 1613 (94.8%) reported both average age and BW at first calving on the questionnaire administered by a NASS enumerator. The reported operation-specific average age at first calving ranged from 18 to 36 months. The reported operation-specific average BW at first calving ranged from 306.2 to 725.8 kg.

3.1. Comparison of reported and observed ages at first calving

For 215 Holstein operations, where ages of first-lactation heifers were observed on the calving log (and that also reported an average age at first calving on the questionnaire administered by a NASS enumerator), the age of first-lactation heifers observed at calving ranged from 16 to 87 months. The 5^{th} and 95^{th} percentiles were 23 and 35 months, respectively. 'Observed' age at first calving refers to ages observed on the calving log, and 'reported' age at first calving refers to the average age reported on the NASS questionnaire.

The number of first calvings observed per operation ranged from 1 to 39, with a median of 5.

The mean observed age per operation for first-calf dairy heifers giving birth ranged from 18.0 to 51.6 months (mean = 27.1 months). In contrast, the mean reported age at first calving for these 215 Holstein operations was 25.8 months ($p < 0.05$). Twenty-three (10.7%) and 130 (60.5%) operations, respectively, reported an average age at first calving identical to or less than the mean age at calving of first lactation heifers observed on the operation ($p < 0.05$ by sign test).

The median observed age of first-calf dairy heifers giving birth ranged from 18.0 to 49.0 months per operation (mean of medians 26.8 months). Fifty-three (24.7%), 103 (47.9%) and 59 (27.4%) operations reported an average age at first calving identical to, less than, or greater than the median age at calving of first-lactation heifers observed on the operation ($p < 0.05$ by sign test).

Table 4
Results of stepwise logistic regression (using SAS and SUDAAN) for factors associated with reporting age ≤ 25 months and BW ≥ 544.3 kg at first calving for Holsteins

Variable	Response					
	SAS model			SUDAAN model		
	Odds ratio	95% CI	P	Odds ratio	95% CI	P
Region						
West	3.74	2.28–6.14	< 0.001	3.67	1.67–8.08	0.002
Midwest	2.76	1.70–4.48	< 0.001	3.54	1.61–7.80	0.003
Northeast	2.71	1.60–4.59	< 0.001	2.33	1.00–5.45	0.057
Southeast	1	–	–	1	–	–
No. of milking and dry dairy cows						
< 100 cows	0.60	0.40–0.88	0.009	0.59	0.34–1.01	0.062
100–200 cows	0.66	0.45–0.96	0.029	0.61	0.34–1.10	0.108
> 200 cows	1	–	–	1	–	–
Rolling herd average milk production						
< 7711 kg	0.57	0.42–0.78	< 0.001	0.48	0.29–0.80	0.007
≥ 7711 kg	1	–	–	1	–	–
Mean age of calves when first offered hay or other roughages						
≤ 20 days	0.72	0.55–0.96	0.025	–	–	–
> 20 days	1	–	–	–	–	–
Unweaned heifers are tied in cow barns						
Yes	0.35	0.18–0.70	0.003	0.39	0.17–0.91	0.035
No	1	–	–	1	–	–
A computer is used for recordkeeping						
Yes	1.54	1.17–2.03	0.002	1.83	1.16–2.88	0.035
No	1	–	–	1	–	–

3.2. Operations approaching target calving age and weight

The mean operation average age at first calving (estimated from SUDAAN) was 25.9 ± 0.1 months, and the mean operation average BW at first calving was 508.7 ± 1.8 kg. Table 2 summarizes the distributions of average age at first calving and average BW at first calving for Holstein operations as reported on the questionnaire administered by a NASS enumerator. Very few Holstein operations (2.7 ± 0.5%) reported both average age ≤ 24 months and average BW ≥ 550 kg at first calving. Thus, to allow for statistical comparisons, the target ranges were modified slightly beyond the current recommendations. The weighted national estimate (using SUDAAN) was 14.6 ± 1.3% of Holstein operations reporting first calvings in the modified target range of ≤ 25 months of age and ≥ 544.3 kg at first calving. Table 3 presents the results by herd characteristics.

3.3. Multivariable models

Results from the two models were similar (Table 4). However, the model from SAS (but not that from SUDAAN) showed that operations, where the mean age at which calves were first fed hay or other roughages was > 20 days, were more likely to report approaching the targets than operations where the mean age at which calves were first fed hay or other roughages was ≤ 20 days.

4. Discussion

The data in the NDHEP were from randomly selected herds representing 77% of the US dairy cow population and 47% of US producers with dairy cows (Heinrichs et al., 1994). A limitation of many previous livestock studies in the US was that operations were not selected widely to permit statistically significant inferences relating to larger populations (King, 1990). The NASS list frame (from which a probability-based sample was selected for the NDHEP) listed nearly all agricultural producers in the US (Heinrichs et al., 1994). An area frame (a census of all producers from randomly selected land areas in the US) was used to adjust for incompleteness of the NASS list frame (Heinrichs et al., 1994).

Because dairy operations with < 30 dairy cows were not included in the NDHEP (Heinrichs et al., 1994) and because this analysis was restricted to primarily Holstein herds, the results of this study are not necessarily generalizable to very small or non-Holstein dairy operations. Similarly, the results do not apply to states not included in the NDHEP.

Although there was a general tendency for producers to underestimate average age at first calving, this was not universally the case. Furthermore, the observed age of first-lactation heifers was highly skewed toward older heifers.

The reported average age at first calving might have been more reflective of the operator's goals than what was really taking place. However, the questionnaire asked for the 'average' age at first calving — not specifically the mean or median. Many respondents might have interpreted the question as asking for the age at which the plurality of heifers gave birth. In a distribution skewed toward older heifers, one would anticipate the mean and median to exceed the mode (Snedecor and Cochran, 1967). Therefore, in many farms, the age at which most heifers calved might, in fact, have been less than the mean or median age of heifers at calving on the farm.

As with any survey, a certain degree of nonsampling error was destined to occur (Sukhatme and Sukhatme, 1970). Erb et al. (1996) reported an overall discrepancy rate of 8.5% in a test–retest of a portion of the NDHEP. No changes were made to the responses of individual producers. In many cases, the number of births observed was not sufficient to override the judgment of the producer. However, categorizing the data into operations that reported themselves within and not within given ranges mitigated some of the noise induced by the nonsampling error.

Seventy-nine (4.6%) of Holstein operations did not report an average age at first calving, and 84 (4.9%) of Holstein operations did not report an average BW at first calving. Thus, the results of this analysis may refer more precisely to 96.6 $\pm$ 0.6% of Holstein operations within the study population that were able to report both average age and BW at first calving. It is a plausible hypothesis that most of the operations that did not report an average age and BW at first calving also did not achieve the recommended age and BW at first calving—which might suggest that even fewer operations are actually achieving recommended age and BW at first calving than reported here. One reason missing data items from the NDHEP were not imputed was that further analyses that treated imputed values, as if they were known with certainty, would have systematically underestimated variability (Rubin, 1987), thus invalidating tests of significance. Another is that such imputations would have assumed complete randomness in being missing.

Although some NDHEP participants provided data for additional questionnaires beyond the questionnaire administered by a NASS enumerator (1177 or 65.0% answered a questionnaire that dealt with dairy heifer health, and 1123 or 62.0% answered a questionnaire that dealt with dairy heifer management; US Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services, 1993a), data from these questionnaires were not used in this analysis to avoid losing a significant number of observations and to maintain a national focus. In addition, since relatively few operations reported achieving recommended age and BW at first calving, reducing the sample size to accommodate additional questions would have made it more difficult to identify factors associated with the outcome variable. Furthermore, some bias between those that answered the additional questionnaires and those that did not may have existed. However, many of the variables examined here (such as housing of heifers, feeding colostrum, feeds given after colostrum, etc.) have important health implications (Heinrichs, 1993; Simensen, 1981).

As in previous NDHEP data analyses (Garber et al., 1994; Losinger and Heinrichs, 1996; Losinger et al., 1995), operations with missing data for screened variables were excluded from multivariable analyses. Results could have been biased if reasons for not responding to particular items were correlated with values of the variables (Rubin, 1987).

Incorporating the sample weights into the analysis was important to reduce bias in the error estimates (Korn and Graubard, 1995; Research Triangle Institute, 1992). In the

NDHEP, larger dairy operations were sampled at a higher rate than smaller dairy operations, and therefore contributed less to the error of estimates than smaller dairy operations (Heinrichs et al., 1994). A limitation of using SUDAAN is that deviance estimates given by SUDAAN cannot be used in the usual way to build logistic models, since the deviance estimates do not reflect the design weights or design stratification or clustering. One has little choice but to examine P-values of variables added to the model. Performing the multivariable analysis two ways (once using SAS, which assumes simple random sampling, and again using SUDAAN, which takes the sample design into account) served to validate the study findings.

Although this study found statistically significant associations between certain management practices and the achievement of a certain age and BW at first calving for Holsteins, this did not perforce imply that these management practices were the cause of achieving first calvings within the specified ranges.

Many of the reported mean ages and BWs at first calving were considerably outside of recommended standards for age and BW at first calving. This may indicate that the dairy industry in the US has considerable room for improvement in terms of achieving recommended age and BW at first calving. However, although heifers that calve earlier and with higher BW at first calving may yield more gross revenue to the producer, the net benefits need to be examined (Chase, 1993). Many dairy farmers may have already decided that achieving recommended age and BW at first calving is not feasible economically. For example, in the more humid Southeast region of the US, a considerable amount of money would be required to ensure an environment of less heat stress on dairy heifers to attain the previously recommended age and BW at first calving.

Operations with rolling herd average milk production (RHAMP) > 7711 kg were twice as likely to report achieving first calvings in the target age and BW ranges as compared with operations with RHAMP < 7711 kg. Management practices associated with increased RHAMP have been examined (Losinger and Heinrichs, 1996). Positive associations between heifer growth and herd production have been previously reported (Heinrichs and Hargrove, 1987; Miller and McGilliard, 1959). Higher-producing herds are more carefully managed than lower producing herds (Chase, 1993; Funk, 1993). Genetics also play a role in milk production (Funk, 1993).

Operations that used a computer for recordkeeping were more likely to report the target age and BW at first calving than operations that did not use a computer. Advantages to producers of in-farm databases and knowledge-based analysis programs have been well documented (Spahr, 1993). Advances in computerized recordkeeping systems present a new technology to enhance the capability for herd management and decision-making (Spahr, 1993). Although the presence of some nondifferential bias is plausible (i.e., operations that use a computer know more precisely the age and BW of heifers at first calving and report themselves in the optimum category for age and BW at first calving), its effect is not measurable.

Keeping preweaned heifers tied in a barn with cows was associated with reduced odds of reporting target age and BW at first calving. Nationally, $15.9 \pm 1.3\%$ of producers reported keeping preweaned heifers tied in a barn with cows during the winter months ($13.5 \pm 1.2\%$ of producers reported doing this in the summer months) (US Department of Agriculture:Animal and Plant Health Inspection Service:Veterinary Services, 1993a). Producers that reported keeping preweaned heifers tied in a barn with cows during the winter months were quite likely also to report keeping preweaned heifers tied in a barn with cows during the summer months ($\rho = 0.925$). Placing preweaned calves close to cows may have some benefit in very cold environments (Simensen, 1981). However, tying preweaned heifers in barns with cows is not generally recommended in most of the US (Heinrichs, 1993). Pathogens often encountered in calf-housing environments have been shown to have a deleterious impact on growth, feed efficiency, and incidence of disorders (Heinrichs, 1993; Losinger et al., 1995; Simensen, 1981). Calves tied in barns with cows may be at increased risk for enzootic pneumonia. Warnick (1994) showed that calfhood respiratory disease before 90 days of age lead to reduced growth and a 3-month delayed age at first calving among affected heifers.

5. Conclusion

The wording of the NDHEP questionnaire with respect to average age and BW at first calving could have yielded ambiguous results (i.e., producers may have interpreted the question as asking for the mean, median, or age and BW at which the majority or plurality of first calf heifers gave birth). However, the results indicated that the US dairy industry appeared to have considerable room for improvement in terms of attaining recommended age and BW of heifers at first calving. Although not analyzed here, economic factors probably played a role in the operators' decisions that lead to optimizing age and BW at first calving, and, on many farms, the recommended biological optima may not have coincided with the economic optima. Operations with higher milk production, which used a computer and did not tie unweaned heifers in barns with cows, were more likely to produce heifers that calved at a recommended age and BW.

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